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5.4.1 Linear Fluorescent Lighting

In U.S. commercial buildings, lighting accounts for 23% of total energy consumption (1995) and 46% of total electricity consumption. The vast majority of interior lighting in commercial buildings is provided with linear fluorescent fixtures (luminaires) and lamps. There have been significant improvements in fluorescent lighting technologies in recent years, including new higher-quality lamps, improved electronic ballasts, more advanced luminaires, and better controls.

Opportunities

Whenever an interior space is being renovated or reconfigured, the lighting should be carefully examined. Changing the location of workspaces, adding or moving interior partitions, replacing ceilings, and even painting walls will alter the characteristics of, and provide an opportunity for upgrading, existing lighting. Substantial savings are often possible with reliance on task lighting where existing, uniformly lit spaces include defined task areas. When specifying systems for a new space, always require lighting to be efficient, and look for opportunities to integrate daylighting strategies.

Technical Information

Fluorescent lighting is the best source for most Federal lighting applications because it is efficient and can be switched and controlled easily. Modern linear fluorescent lamps have good color rendering and are available in many styles. Lamps are classified by length, form (straight or U-bend), tube diameter (T-8, T-5, etc.), wattage, pin configuration, electrical type (rapid- or instant-start), color rendering index (CRI), and color temperature. When specifying a lighting system, be sure that the lamp and ballast are electrically matched and the lamp and fixture optically matched.

Fluorescent lamp diameters are measured in 1/8-in. increments—T-12s are 12/8 in. or 1-1/2 in. in diameter; T-8s are 1 in. Most fluorescent lamps are straight, though T-8s and T-5s are also available in U-bend or folded configurations. (Until the late 1990s, T-5s were only available folded, but straight-tube T-5s are becoming more common.) Straight-tube fluorescent lamps are most often used in 1x4-, 2x4-, and 1x8-ft luminaires; folded lamps are used for smaller, square fixtures—lxls or 2x2s. Typical linear fluorescent lamps are compared in the table below; note that efficacy (lumens per watt) is higher with smaller-diameter lamps.

COMPARISON OF FLUORESCENT LAMPS

Lamp Type	T-12	T-12 ES	T-8	T-5*
Watts	40	34	32	54
Initial lumens	3,200	2,850	2,850	5,000
Efficacy (lm/W)	80	84	89	93
Lumen depreciation**	10%	10%	5%	5%

* High-output T-5 in metric length
** Change from "initial lumens" to "design lumens" Source: Philips Lighting

Color rendering of fluorescent lamps is very important. Modern, efficient fluorescent lamps use rare-earth phosphors to provide good color rendition. The color rendering index describes how a light source affects the appearance of a standardized set of colored patches under standard conditions. A lamp with a CRI of 100 will not distort the appearance of the patches in comparison to a reference lamp, while a CRI of 50 will significantly distort colors. T-8 and T-5 lamps are available only with high-quality phosphors that provide CRIs greater than 80. The minimum acceptable CRI for most indoor applications is 70; levels above 80 are recommended.

Color temperature influences the appearance of luminaires and the general "feel" in the space. Low color temperature (e.g., 2,700K) provides a warm feel that is similar to light from incandescent lamps; 3,500K provides a balanced color; and 4,100K emits "cooler" bluish light. Standardizing the color temperature of all lamps in a room or facility is recommended.

Specify electronic ballasts with all linear fluorescent lighting. These are significantly more energy-efficient than magnetic ballasts and eliminate the hum and flicker associated with older fluorescent lighting. Dimming electronic ballasts are also widely available.

Select luminaires that are appropriate for the tasks being performed. Reflectorized and white industrial fixtures are very efficient and good for production and assembly areas but usually inappropriate for office applications. Lensed fluorescent fixtures ("prismatic lens" style) typically result in too much reflected glare off computer screens to be a good choice for today's electronic office. In areas with extensive computer use, common practice is to install "parabolic" luminaires, which minimize high angle light that can cause reflected glare in computer screens; however, these may result in unpleasant illumination with dark ceilings and walls. Instead, for tall ceilings—over 9 ft (2.7 m) in height—use direct/indirect pendant luminaires. For lower ceilings—8 ft 6 in. (2.6 m)—consider parabolic luminaires with semi-specular louvers and provide separate wall-washing to minimize high contrast.

Do not select luminaires based solely on efficiency. Some of the highest-efficiency luminaires have inferior photometric performance. The most effective

$$\text{Luminaire Efficiency Rating} = \frac{\text{Fixture efficiency x Lamp lumens x No. of lamps x Ballast factor}}{\text{Input watts}}$$

luminaires are usually not the most efficient, but they deliver light where it is most needed and minimize glare. The new Luminaire Efficiency Rating (LER) used by some fluorescent fixture manufacturers makes it easier to compare products. Since the LER includes the effect of the lamp and ballast type as well as the optical properties of the fixture, it is a better indicator of the overall energy efficiency than simple fixture efficiency. An LER of 60 is good for a modern electronically-ballasted T-8 fluorescent fixture; 75 is very good and close to "state-of-the-art."

Provide for control of light levels. One option is dual-level lighting (tandem or split-wiring) so that a 50% lighting level can be obtained when desired (check local codes). Another option is either automated or manual dimming using special ballasts and controls. Photocell-controlled dimming is particularly important if there is a significant daylighting component to the lighting design. See *5.4.4 – Lighting Controls*.

Replace 4-lamp T-12 luminaires with half the number of T-8 lamps (usually in the outer lamp positions) and upgrade to electronic ballasts. A lighting designer should be consulted to evaluate the effectiveness of this strategy and the various alternatives.

Avoid using retrofit reflectors that fit into existing luminaires. Except in one- and two-lamp industrial strips, the white-painted inner surfaces of luminaires serve as very effective reflectors. Because highly reflective specular reflectors often produce striated patterns on surfaces being lit and cause light to "dump" beneath the fixture, they can produce worse lighting than the original diffuse reflectors.

Avoid inappropriate retrofits. If original lighting conditions are poor and cause visual discomfort or ineffective light use because of poorly placed fixtures, conversion to T-8s alone will not provide a satisfactory solution. Complete lighting redesign, retrofit, and even complete ceiling replacement to accommodate new lighting may be necessary. Any lighting retrofit should include a lighting design analysis.

Avoid high-intensity discharge lighting, even with high ceilings. Fluorescent lighting is generally far superior, less costly, easier to control, and provides better light quality than even metal halide. For very high ceilings (e.g., in gymnasiums), new high-bay luminaires using multiple T-5 lamps are proving highly successful. In most high-ceiling areas, try to provide a mix of lighting types, including indirect uplighting, downlighting, wall sconces, decorative pendants in lobby areas, etc.

Always transport and store fluorescent lamps horizontally to prevent phosphorus coatings from settling to the ends of the tubes.

Recycle fluorescent lamps and ballasts. All fluorescent lamps contain mercury, which should be kept out of landfills and municipal incinerators. Phosphor coatings also contain harmful materials that should be kept out of the waste stream. Before 1979, nearly all ballasts for fluorescent lamps contained PCBs (polychlorinated biphenyls), which are highly toxic chemicals that bioaccumulate in biological systems through the food chain. Specialized lamp and ballast disposal firms can thermally destroy PCBs and recover mercury from old lamps (see listing below).

☑ In specifying fluorescent lamps, look for low-mercury products that will cause less of this toxic metal to enter the environment if disposal is not handled properly.

References

IESNA Lighting Handbook – 9th Edition, Illuminating Engineering Society of North America, New York, NY, 2000; (212) 248-5000; www.iesna.org.

Lighting guide specifications for lamps, ballasts, luminaires, and reflectors have been developed under the FEMP Federal Relighting Initiative. Software to assist in system selection and design also is available from the FEMP Help Desk at (800) DOE-EREC or from the FEMP Web site at www.eren.doe.gov/femp/.

The *Lighting Upgrade Manual* may be downloaded at www.epa.gov/docs/CGDOAR/gcd_pubs.html#glpubs.

Lighting Waste Disposal (6202J), U.S. Environmental Protection Agency, Office of Air and Radiation, 1994.

Electric Utility Guide to Marketing Efficient Lighting, Western Area Power Administration, Golden, CO, 1990; (303) 231-7504.

Contacts

EPA Green Lights and ENERGY STAR® Programs Hotline: (202) 775-6650.

The National Lighting Product Information Program (NLPIP) of the Lighting Research Center at Rensselaer Polytechnic Institute offers independently evaluated product information, including manufacturer-specific test results on thousands of lamps, fixtures, ballasts, and controls; www.lrc.rpi.edu.

Association of Lighting and Mercury Recyclers, 2436 Foothill Blvd., Suite K, Calistoga, CA 94515; (707) 942-2197.